

The middle and upper part of the succession is composed of normal and restrictive marine subtidal limestones. The vertical distribution of subtidal facies, reflects cyclic changes in water depth. The first record in these deposits is marked by a fluctuation of the environmental deepening (from shallow to deeper domains) and/or ecological changes in the depositional environment (from restrictive to open marine conditions and returning to restrictive conditions).

In the upper part of the succession the peritidal limestones are dominant. The typical facies and facies associations for the peritidal environment are separated in three depositional subtypes: subtidal, intertidal and supratidal. The vertical stacking of the identified facies reflects cyclical changes in water depth. The deposits contain marine and marine restrictive facies accumulated in high or low energy environments. The facies evolution of individual beds or bed sets, indicates a transition between the three depositional zones, represented by lagoons, ponds, beaches, tidal bars, algal-microbial mats and swamps. Rivulariacean-type cyanobacteria played an important role in the carbonate accumulation.

The vertical succession of the carbonate deposits from Piatra Craiului indicate the existence of a gradual transition from slope and shelf margin to subtidal and shoreline facies. This fact indicates the progradation of the carbonate platform during the Lower Cretaceous. In the same time, due to the radical reduction of the accommodation space on the carbonate platform, the main carbonate sedimentary production was generated by cyanobacteria.

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### **A coastal paradise for Aptian microbialites (Early Cretaceous, N Spain)**

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Microbial carbonates are remarkably diverse and abundant in the early Aptian (~120 Myr) coastal carbonates of the Leza Fm (La Rioja, N Spain). They show a great variety of macro- and microfabrics, associated with differing sedimentary environments. This provides a unique opportunity to study the factors underlying development of microbial fabrics and structures.

The Leza Fm is part of the Early Cretaceous Cameros rift basin. Sedimentological analysis reveals that it was deposited in a system of carbonate coastal-wetlands with variable fresh- and seawater influence, composed of: a) carbonate water-bodies with charophytes and dasyclads; b) palustrine plains with common paleosols; c) siliciclastic alluvial environments; d) oncoid channels; e) carbonate water-bodies with ostracodes and miliolids; f) tidally-influenced water-bodies; and g) restricted carbonate-evaporite water-bodies. These environments interfinger throughout the unit, but also show a general retrogradational trend.

Most of the sedimentary environments of the Leza Fm are rich in microbial carbonates: (1) *Oncoids* are common in small channels and facies with strong freshwater influence, and have microfabrics dominated by calcified filaments. (2) *Skeletal stromatolites* occur in the western outcrops associated with cross-bedded sandy grainstones with charophytes and rare dasyclads. They have domical morphologies and well-calcified filamentous microfabrics. (3) *Fragments of dendrolites* are common throughout the coastal-lake facies with charophytes and dasyclads, showing microstructures of delicate branching calcified filaments. (4) *Thrombolites* occur in dasyclad-dominated coastal-lake carbonates of the western outcrops. Their microfabrics are commonly diagenetically altered, but show relict peloidal micrite and calcified filaments. (5) *Fenestral laminites* are common in facies with ostracodes and miliolids in the western outcrops. They show undulose lamination marked by elongate fenestrae. Vertical cracks and vadose calcite cements are common. Their

microfabrics are micritic, clotted-peloidal and agglutinated, with some filament relicts. (6) *Agglutinated oolitic stromatolites* are found in tidally-influenced eastern outcrops with ostracodes and miliolids. They show domical morphologies and microfabrics dominated by trapped ooids and bioclasts and clotted-peloidal micrite. Calcified filaments are rare.

A clear link between particular facies and microbialite types is observed. For example, filamentous microfabrics (oncooids, skeletal stromatolites, dendrolite fragments) occur in freshwater-dominated facies, whereas non-filamentous microfabrics (thrombolites, fenestral laminites, agglutinated stromatolites) are found in facies with stronger marine influence. Thus, microbialite variability in the Leza Fm reflects the diversity of sedimentary environments. We conclude that at this time, coastal-wetlands at the crossroads of marine and freshwater realms provided a broad variety of hydrochemical and hydrodynamic settings that could promote the development of differing microbial communities and products.

Furthermore, the early Aptian was a period of microbialite abundance in many carbonate platforms located as far afield as Arabia, Western Europe, and the Pacific Ocean. Global oceanographic and climatic changes have been suggested as possible causal factors. Comparison of the Leza Fm transitional-coastal setting with coeval carbonate platforms could help to further understand these early Aptian microbialite paradises.

### **Microbial carbonate reef components in the mid-Triassic Italian Dolomites: A biogeochemical approach**

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Triassic carbonate buildups of the Dolomites have for decades been regarded as classic examples of ancient coral reefs and have been the subject of extensive research. During the mid-Triassic reefs underwent important changes, evolving from reefs mainly composed by sponges, seafloor crusts, and calcimicrobes such as *Shamovella*, to more modern-looking coral-algal associations with clotted-peloidal crusts. We examined good examples of both types at Punta Grohmann and Alpe di Specie. The Punta Grohmann samples of high-rise platform margin reef rock are from erratic 'Cipit Boulders' in Late Ladinian-Middle Carnian basal sediments (Wengen and San Cassiano formations). These blocks escaped the extensive dolomitization that affected the buildups, and preserved their original mineralogy and organic content. The Alpe di Specie samples are from small Late Carnian patch reefs in the Heiligkreutz Formation, and are widely regarded as in situ or nearly in situ. Their coral-sponge-algal framework cavities contain distinctive clotted-peloidal micrite microfabric. Despite their small size, these bioherms are among the earliest examples of skeletal framework reefs whose major components are broadly comparable with those of present-day tropical coral reefs. We carried out biogeochemical analyses on selected samples from both localities to characterize the organic matter and bacterial metabolic signatures. These included UV epifluorescence observations, Total Organic Carbon (TOC) content, FT-IR spectroscopy and biomarkers analyses. Rare Earth Elements (REE) distributions were also investigated to determine the oxidation state in which these deposits precipitated.

The Punta Grohmann and Alpe di Specie reefs are not very different in age but show significant differences in components, structure and fabrics, reflecting contrasting depositional environments. Punta Grohmann sponge-microbial reefs contain biomarkers for various bacteria including cyanobacteria but lack specific molecules typical of sulfate-reducing bacteria. This suggests that aerobic bacteria were able to directly degrade the organic matter from primary producers, and is consistent with well-oxygenated depositional conditions indicated by REE values, and with the high-energy platform margin setting in which they formed. Alpe di Specie scleractinian patch reefs contain sulfate reducing bacteria

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